Functionally substituted dienes based on α-pinene

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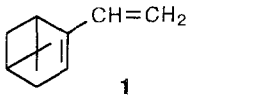
Dienes containing an α-pinene fragment were synthesized from myrtenal and functionally substituted phosphonates. Their structures were studied using ^{1}NMR, IR, Raman, UV, and CD spectroscopy.

Key words: α-pinene, myrtenal, Horner—Emmons reaction, synthesis, dienes, structure, ^{1}NMR, IR, Raman, UV, and CD spectra.

Natural bicyclic terpenes and their derivatives are widely used in fine organic synthesis,[1] in the production of perfumes,[2] and in the synthesis of biologically active compounds. The presence of a double bond, a reactive four-membered ring, and chiral centers in pinenes attract the attention of many investigators.

The preparation of diene derivatives of α-pinene and their application in syntheses have been described previously.[4—7] It has been established that treatment of nopol tosylate with potassium *tert*-butoxide results in 6,6-dimethyl-2-vinylnorpinene (nopadiene (**1**)).[5]



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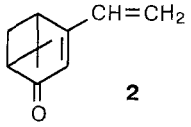

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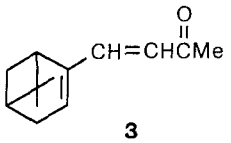

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Verbenone synthesized by the oxidation of α-pinene undergoes aminomethylation according to Mannich followed by decomposition of the aminomethyl derivative during distillation to afford 6,6-dimethyl-4-vinyl-3-norpinene-3-one (**2**) (see Ref. 6).

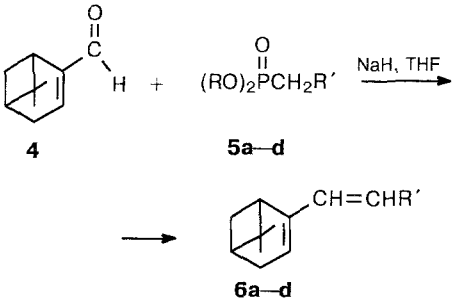
Myrtenal, obtained by the oxidation of α-pinene under aldol condensation conditions, reacts with acetone[7] to give dienone (**3**).

Taking into account the high reactivity of dienes, the synthesis of functionally substituted nopadiene **1** derivatives is of interest. The reaction of carbonyl compounds with carbanions of substituted phosphonates (the Horner—Emmons reaction)[8] and phosphonium salts (the Wittig reaction)[9] is known to be a convenient method for the formation of the C=C bond.

In some cases the Horner—Emmons reaction is more convenient practically and occurs more stereoselectively.[10] Hence, in order to synthesize functionally substituted dienes containing a pinene fragment, we studied the reaction of myrtenal (**4**), the simplest aldehyde of the pinene series, with different phosphonates (**5a—d**) in the presence of bases.

To avoid the side products formed when strong bases are used (alcoholates, alkali, *etc.*), we prepared the carbanions by treatment of phosphonates with sodium hydride in THF (Scheme 1).

Scheme 1



4 **5a—d** **6a—d**

R = Me

R′ = CN (**a**); COOMe (**b**); COOEt (**c**); $CONEt_2$ (**d**)

The reactions were carried out at room temperature. The structures of compounds **6a—d** were confirmed by spectral methods. ^{1}H NMR spectroscopy gave unambiguous information about the relative location of the substituents at the *exo*-C=C bond. The protons of the HC=CH fragment in compounds **6b—d** are *trans* to each other (the coupling constant is ~16 Hz).

It is worth noting that the Horner—Emmons reaction of substituted acroleins, which can be hypothetically regarded as acyclic analogs of myrtenal **4**, affords

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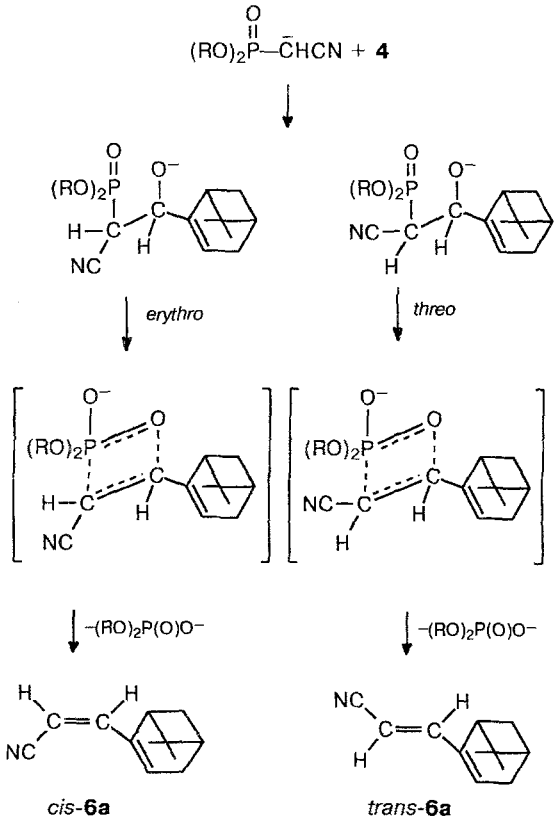
products with solely *trans*-located substituents at the newly formed double bond.[11]

However, when diene **6a** was synthesized, ^{1}H NMR data showed the formation of ~15 % of an isomer containing *cis*-protons at the C=C bond (coupling constant ~11 Hz) and ~ 85 % of the *trans*-isomer (coupling constant ~16 Hz). One can conclude from these facts that steric effects affect the structure of the dienes **6** formed. Thus, according to the Horner—Emmons reaction scheme,[12] the formation of a *trans*-isomer should be preferable, because, in our opinion, this bicyclic fragment determines the direction along which the reacting molecules **4** and **5** approach each other (Scheme 2).

Scheme 2



The partial formation of the *cis*-isomer **6a** probably results from the fact that the CN group is less bulky than C(O)R and C(O)NR$_2$, and the *erythro*-form of the product can therefore be obtained when the carbanion derived from phosphonate **5a** is added to the carbonyl group of myrtenal **4**. Then the *erythro*-adduct is transformed into the *cis*-isomer while the *threo*-adduct is transformed into the *trans*-isomer.

The IR spectra of compounds **6a—d** contain intense absorption bands in the 1610—1630 cm^{-1} region and at 980 cm^{-1} that correspond to the vibration of the conjugated C=C bond. The carbonyl group in compounds **6b** and **6c** absorbs in the 1720—1725 cm^{-1} region. We should note the very high intensity of the absorption band in the 2220 cm^{-1} region, which probably results from interaction of the C≡N group with the diene system.

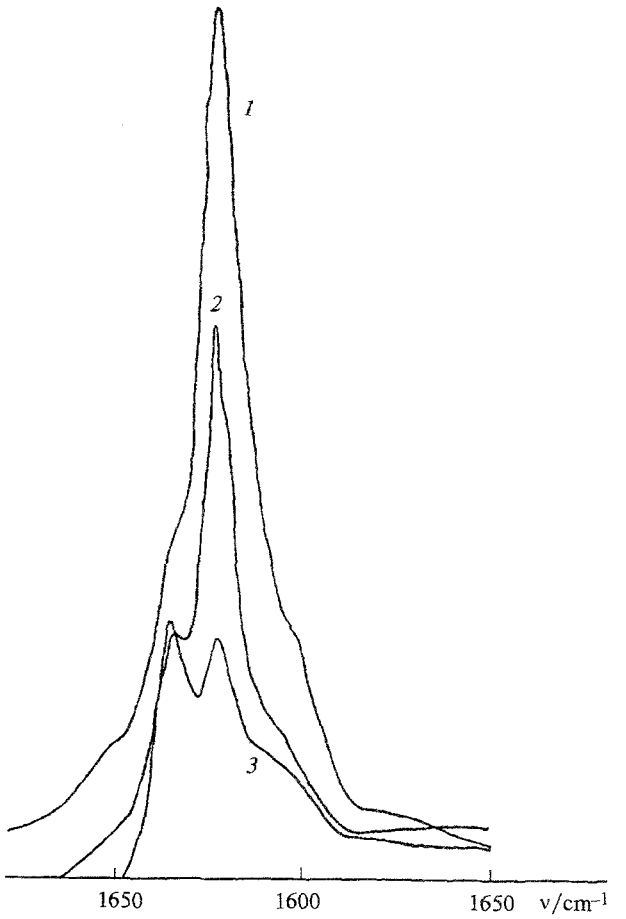


Fig. 1. Raman spectra of compound **6b**: *1*, without a solvent; *2*, in CCl_4; *3*, in acetone.

The Raman spectra of compounds **6a—d** indicate the existence of a conjugated system of double bonds; the abnormally high intensity of the ν(C=C) band may be explained by the *trans*-localization of the *endo*- and *exo*-double bonds relative to each other. Table 1 presents

Table 1. Raman spectra of compounds **6a—d**

ν	6a	6b	6c	6d
C=C	1593 w 1610 vs	1602 sh 1620 vs 1635 sh	1602 sh 1620 vs	1597 vs
C=O	2214* vs	1707 sh 1720 s	1707 m	

* — ν(C≡N).

Table 2. UV and CD spectra of compounds synthesized

Compound*	λ_{max}/nm exp.	λ_{max}/nm calc.**	log ε	$\Delta\varepsilon_\lambda$ Cotton effect
6a	271.0	278	4.033	−284.5
6b	277.3	278	3.992	−381.5
6c	276.6	278	4.307	−183.3
6d	274.9	278	4.19	−720.04

* In MeCN. **From Ref. 13.

the vibrational frequencies of ν(C=C) and ν(C=O) in the Raman spectra of compounds **6a—d**.

A study of the effect of the polarity of the medium showed that redistribution of the intensities of the ν(C=C) and ν(C=O) bands occurs in compound **6d**. Thus, the band at 1655 cm^{-1} is more intense in CCl_4 than in acetone. This can probably be explained by the hindered rotation around the =C—C= bond in the diene moiety.

The Woodward rule, which determines the empirical correlation between the position of an absorption maximum in the UV region and the structure of substituents at double bonds,[13] is widely used in organic chemistry in the investigation of conjugated systems.

α-Pinene has weak absorption with a maximum at 218 nm (in MeCN), which is typical of an isolated double bond (π—π*-transition). Compounds **6a—d** have a longer conjugated system, which should result in displacement of the absorption maxima to the long-wave region. The experimental and calculated[13] positions of the absorption maxima of compounds **6a—d** are given in Table 2.

The small deviation of the experimental λ_{max} for compounds **6a** and **6d** from the calculated values may be due to the influence of *n*—π*-transitions in the C—N bond.

It is known that dienic non-planar hydrocarbons can possess internal chirality.[14,15] It has been shown previously that if one of the terminal C atoms in a system of conjugated double bonds deviates from the plane formed by the other three atoms, the Cotton effect in the CD spectra can be negative or positive, depending on the direction of deviation. Dienes **6a—d** display negative Cotton effects in the absorption region of the dienic chromophore. One can conclude from the data given in Table 2 that the terminal atom of the *exo*-C=C bond in compounds **6a—d** is deviated counterclockwise from the plane formed by the three other carbon atoms of the diene system, provided that the endocyclic double bond is fixed horizontally.[14]

Thus, novel dienes of the pinene series have been obtained starting from myrtenal and carbanions of functionally substituted phosphonates.

Experimental

^1H NMR spectra were recorded on a Varian T-60 spectrometer in CCl_4 with Me_4Si as the internal standard. IR spectra were obtained on a UR-20 spectrophotometer. UV spectra were recorded in MeCN on a Specord M-40 spectrophotometer. Raman spectra were obtained on a RTI-30 spectrometer (Dilor). An ILA-120 Ar^+ laser was used as the light source. The liquid samples were placed into capillaries 5 mm in diameter. CD spectra were measured in MeCN on a Jasco 500A spectropolarimeter (Japan). Specific rotations were determined on a Polamat A polarimeter.

2-(2-Cyanovinyl)-6,6-dimethyl-2-norpinene (6a). Dimethyl α-cyanomethylphosphonate (16.8 g, 0.112 mol) was added dropwise at ~20 °C to a solution of NaH (2.7 g) in 100 mL of THF so that the temperature of the reaction mixture did not exceed 30 °C. The mixture was stirred for 1 h at ~20 °C, then myrtenal (16.9 g, 0.112 mol) was added dropwise. The solution was stirred for 2 h at ~20 °C, then the reaction mixture was worked-up with water and extracted with ether (3×100 mL). The ethereal extract was dried with $MgSO_4$ and concentrated. The residue was distilled *in vacuo* to give 9.1 g (47 %) of compound **6a**, b.p. 70—72 °C (2 Torr), d_4^{20} 0.9820, n_D^{20} 1.4863, $[\alpha]_D^{20} = -6.2$ (*c* 6.6, benzene). Found (%): C, 82.90; H, 8.75; N, 7.92. $C_{12}H_{15}N$. Calculated (%): C, 83.23; H, 8.67; N, 8.09. IR, ν/cm^{-1}: 2220 (CN), 1610 (C=C). ^1H NMR (CCl_4), δ: 0.78 (s, 3 H, Me (*endo*)); 1.36 (s, 3 H, Me (*exo*)); 5.10 (d, 1 H, J = 16 Hz); 5.88 (m, 1 H); 6.94 (d, 1 H, J = 16 Hz); (*trans*-isomer); 4.90 (d, 1 H, J = 11 Hz); 5.94 (m, 1 H); 6.48 (d, 1 H, J = 11 Hz), (*cis*-isomer); isomer ratio 85 : 15.

2-(2-Methoxycarbonylvinyl)-6,6-dimethyl-2-norpinene (6b) was obtained in 31 % yield similarly to **6a**. B.p. 72—74 °C (2 Torr), d_4^{20} 1.0384, n_D^{20} 1.5270, $[\alpha]_D^{20} = -5.6$ (*c* 5.3, benzene). Found (%): C, 75.40; H, 8.46. $C_{13}H_{18}O_2$. Calculated (%): C, 75.72; H, 8.74. IR, ν/cm^{-1}: 1720 (C=O), 1625 (C=C). ^1H NMR (CCl_4), δ: 0.79 (s, 3 H, Me (*endo*)); 1.38 (s, 3 H, Me (*exo*)); 5.61 (d, 1 H, J = 15 Hz); 5.90 (m, 1 H); 7.11 (d, 1 H, J = 15 Hz).

2-(2-Ethoxycarbonylvinyl)-6,6-dimethyl-2-norpinene (6c) was obtained in 60 % yield similarly to **6a**, b.p. 95—97 °C (3 Torr), d_4^{20} 0.9820, n_D^{20} 1.5059, $[\alpha]_D^{20} = -4.0$ (*c* 7.1, benzene). Found (%): C, 75.92; H, 8.72. $C_{14}H_{20}O_2$. Calculated (%): C, 76.30; H, 9.09. IR, ν/cm^{-1}: 1725 (C=O), 1635 (C=C). ^1H NMR (CCl_4), δ: 0.80 (s, 3 H, Me (*endo*)); 1.38 (s, 3 H, Me (*exo*)); 5.87 (d, 1 H, J = 16 Hz); 5.86 (m, 1 H); 7.08 (d, 1 H, J = 16 Hz).

2-(2-Diethylaminocarbonylvinyl)-6,6-dimethyl-2-norpinene (6d) was obtained in 51 % yield similarly to **6a**, b.p. 123—125 °C (2 Torr), d_4^{20} 0.9900, n_D^{20} 1.5490, $[\alpha]_D^{20} = -5.9$ (*c* 4.7, benzene). Found (%): C, 74.74; H, 9.97; N, 4.96. $C_{16}H_{25}NO$. Calculated (%): C, 77.73; H, 10.12; N, 5.66. IR, ν/cm^{-1}: 1645 (C=O), 1605 (C=C). ^1H NMR (CCl_4), δ: 0.80 (s, 3 H, Me (*endo*)); 1.38 (s, 3 H, Me (*exo*)); 5.80 (m, 1 H); 5.98 (d, 1 H, J = 15 Hz); 7.08 (d, 1 H, J = 15 Hz).

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